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[The following are translations of selected articles in the Russian-language monthly journal AVIATSIYA I KOSMONAVTIKA published in Moscow. Refer to the table of contents for a listing of any articles not translated.]

Major-General Yanakov on Future of Air Forces Schools

93UM0679A Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 2, Feb 93 (signed to press 9 Feb 92) pp 2-4

[Article by Major-General of Aviation Ya. Yanakov under the rubric "Military Reform and Higher Educational Institutions": "The Five-Year Plan—Pluses and Minuses"]

[Text] *The higher military aviation schools for pilots and navigators of the Air Forces will shift to a five-year course of study for cadets starting with the 1993/94 academic year, by order of the Minister of Defense of the Russian Federation. This is expected to make it possible to give the graduates a basic higher professional education at the level of contemporary world standards.*

The realization of the new system for training aviation cadres also entails the appearance of a number of problems whose resolution frequently goes beyond the bounds of the jurisdiction and capabilities of not only the leadership of the military schools, but also the bodies for their immediate administration. The editors, in giving the floor to today's author, are counting on an interested and attentive attitude toward the issues raised by him on the part of the corresponding directorates and services of the Air Forces high command. We hope that the discussion thus started will be continued by the readers, and first and foremost by those who have a direct relationship to this topic—the commanders, professors, instructor and training personnel, cadets and attendees of the schools and academies of the Air Forces.

The training of a pilot costs the state hundreds of millions of rubles. There are scientific-research centers in some countries that specialize in working on problems of reducing the cost and improving the quality of the training of aviation personnel. The "2000" program has now been adopted in the United States; it envisages the creation of efficient training complexes that permit a significant optimization of this process. We have also approached the solution of this problem in earnest in our country, owing to the cutbacks that have begun in the armed forces.

It has become obvious that the staffing levels of Air Forces military-educational institutions are intolerably large (more than 35 percent of the overall size of the Air Forces). The way out of this situation would seem to be a simple one—several of the schools need to be closed. But more intent study of the question shows that a mechanical reduction in them could lead to a repetition of the mistakes that were made in 1959 by the country's leadership, which caused an acute scarcity of aviation personnel several years later. They soon had to resurrect the pilots' schools that had been abolished (the Borisoglebsk and Barnaul VVAULs [Higher Military Aviation Schools for Pilots]), and catch up for the omission for even longer than that.

The leadership of the Air Forces higher-educational institutions has been conducting research over the last three years to make the training of flight cadres more efficient. It has made it possible to conclude that it is essential to take radical steps that would fundamentally improve the educational process and raise the quality of training of the cadets to the required level with a decrease in the amount of permanent staffing of the higher-educational institutions (by 30 percent).

This conceptual framework for the training of flight cadres, it seems to me, is organically inherent in re-organizing the planned composition of the aviation group on the territory of Russia, and facilitates over-coming the shortage of specialists along with a further rise in the fighting ability of aviation units. Some 10—15 years are planned for its realization—a deadline that makes it possible to accomplish what is conceived without haste.

Our assumptions are supported by the Minister of Defense and the Commander-in-Chief of the Air Forces. The flight higher-educational institutions have been converted to five-year study, and the development of new curriculums and programs has begun. The first step on the road to reform has been taken. The question is whether others will follow. I do not ask this by accident, since even today the incarnation of our ideas has been called into question. The increased course of study of the pilots, of course, will not solve the problem in and of itself. It can provide results only as part of other measures that are, by the way, not included in the program for the overall re-organization of the system of training for aviation personnel.

By considering the training of pilots in light of the re-organization of the Air Forces of Russia being pursued and the Law on the Reform of Higher Education, we should determine first of all just what sort of specialist we need, and then give answers to the following questions:

—do the education and professional training of graduates correspond to the level of technical complexity of the new aircraft systems entering service with the Air Forces, and what are the prospects for their further improvement?

—is the intellectual cultivation of the personality ensured in training at an aviation higher-educational institution, so as to correspond to the social changes in society and the development trends of statehood in Russia?

—is the future pilot ready for service under contract, under which he can change the nature of his activity under certain conditions in a way that is painless for him and society?

The contemporary combat aircraft system is a kind of "minifactory." But its on-board computers and other complex systems that have absorbed the advanced achievements of science and technology and, aside from

everything else, are developing constantly, are all inert without the participation of the person. The training of specialists should prove to be, at a minimum, an order of magnitude ahead of scientific and technical progress.

Let us analyze what we have been teaching the cadets at the schools to this point. Almost a third of study time, starting in the second year of training, they are in practical flight activities. To speak of any rise in the level of their theoretical training during this period is to engage in self-deception. And it is conducted, bluntly speaking, with one aim anyway—to meet formally the norms for the hours of classes stipulated for higher schooling. You will thus agree that the training of specialists with higher education within the former framework is impossible in the face of the new requirements. Cadets at the flight higher-educational institutions, you may recall, year after year studied only the minimum number of disciplines whose assimilation was necessary before basic practical flight activity. The whole educational process was linked with that, and naturally did not permit the observance of elementary principles and methods of teaching. What is more, there was not enough time for a profound study even of the special sciences necessary to the future pilot. Need it be said that the fundamental (general-theoretical) portion of the schooling, owing to its small volume and the break-up of the program into semesters, did not provide the requisite level of mastery of special disciplines by the cadets. They were thus never trained for operations under special conditions, and little attention was devoted to physical fitness. And we wonder why more than half of all flight accidents are connected with the human factor here. What scientific institution and who can answer the question of how much we would save if we were able to increase the professional longevity of the pilot an average of at least three years?

The volume and content of the current programs at the schools in the humanities are moreover so poor that we cannot speak of any intellectual education of the individual worthy of our country. We openly admit that the flight schools are still oriented more toward the "trade" than toward education. There are still a host of shortcomings here as well. Everyone would agree, for instance, that it is extremely inefficient and irrational to use the teaching time allocated under the old standards for practical flight work. Its quite large volume is determined not by norms for flight time per cadet, but rather a calendar time frame within which one may organize flights with them. It thus frequently turns out that the flights of the training group (air squadron) are conducted while a certain portion of the cadets in them do not become active, owing to shortages of aircraft or the overloaded airspace, among other things. So it obtains that instead of 5—6 hours a week, the cadet at, say, the frontal-aviation schools flies an average of half, and at helicopter schools one third, of the norms. The losses of training time owing to this absurdity are enormous over the training cycle.

The required flight commitments are not ensured with the proportion of training regiments and airfields existing at the schools today, and that means that the loss of training time is apparent. The situation can and must be rectified by decreasing the number of cadets planned for flights. It would moreover be expedient to conduct practical flight work in only two years, rather than three.

There is another nuance here as well. Flights exclusively during the summer months lead to six-month layoffs, which force more than a third of the flying time envisaged under the program to be spent on restoring lost skills of piloting technique. The requirements for the training of cadets in advanced types of flights (weapons delivery in pairs, by day with IFR, at night) are not able to be fully realized. The higher-educational institutions, with quite a few aircraft and airfields, use them for the training of cadets only five or six months out of the year, which not only reduces the operational efficiency of the physical plant for training, but also leads to a considerable increase in the cost of training the flight cadres. About half (!) of the yearly flying time both at the schools and at the aviation training centers falls to the share of the permanent staff, who have openly low qualifications.

A rise in the professional level of training and a reduction in the turnover of instructor pilots is possible only via raising status and pay levels. Only then can we get started with an 18—24 percent reduction in their numbers. The financial resources released thereby, according to our calculations, will be entirely enough for material incentives for the activity of the instructors. The Air Forces command and the Ministry of Defense have the last word on this issue.

The pilot currently completes three stages in his training: flight school—aviation training center (UATs)—line unit. It is entirely obvious that his emergence as an aerial warrior must be considered through the prism of training at all stages. Only in that case can we evaluate the degree of perfection of the system for personnel training.

The cadet completes theoretical training and a program of training on a trainer aircraft with flying time 220—230 hours at the school over four years. The graduates, over 10—11 months at the UATs, master the type of combat aircraft on which they will be flying later, and receive the qualification of military pilot 3rd class. They train for another three-four years after arriving in the line unit so as to become a pilot 1st class, that is, become full-fledged aerial warriors, as they say. You will agree, should the line units really be engaged in the final training of the pilots? But that is just one aspect of the issue. Another is whether it is rational to drag out their training for seven or eight years. The principal share of the accompanying material expenses, after all, go for the practical assimilation of the combat aircraft, with one hour of flying time on it 5—10 times (depending on the type) more expensive than on a trainer. It has been demonstrated in practice that the flying time required for the training of the future pilot depends largely on the cadet's level of assimilation of the trainer aircraft.

Whence a conclusion suggest itself—conduct the flights with the cadets without a break for a span of 15 months, eliminating the month's break, instead of practical flight work drawn out over three years. The graduate could in that case already have reached the 2nd-class level inside the walls of the higher-educational institution, automatically predetermining his success in mastering a combat aircraft in the future without increasing flying time or the time frame for the conduct of practical flight work. It would only remain for the line unit to train the young pilots for a year and a half or two years for combat operations in the full amount. The period of emergence of the pilot in the "school—UATs—line unit" system could thus be reduced to four or five years. Tempting, is it not?

We will be realists. The physical plant of the higher-educational institutions, the level of training of the professors and instructors, the program support for the cadet training process and the degree of perfection of the training complex all do not permit the full realization of the new ideas at once. This means that they must be implemented gradually, to the extent of the creation of the conditions for converting to training in the corresponding directions. The gradual reformation of the system for pilot training would be intelligent on this plane.

The **first stage** envisages the conversion of the schools to a five-year term of study with the realization of the new requirements for higher education, with a focus on flight training for cadets in the later years depending on the individual abilities of each, along with changes in the composition and structure of the higher-educational institutions. It is also essential to provide, in conjunction with this, for the development of new curriculums and programs, improvement of the work of professors and instructors and the conversion to practical flight work at base airfields. Two or three flight schools would then suffice entirely for Russia, instead of the existing five. The first stage could possibly be realized before 1995—1997.

The **second stage** is the further development of the physical plant of the most promising schools, allowing an increase in the number of attendees at them from 600—800 to 1,500—2,000, along with the creation of a refined infrastructure for the higher educational institution. The improvement of the curriculums and programs will make it possible to move to training the graduates for all flight fields and specializations and to adopt a contract training system. The conclusion of that work, including the technical refitting of the flight higher-educational institutions, is possible by 2003—2005.

The **third stage** envisages completion of the transition to flight training for cadets at a new training complex manufactured domestically, and to the training of pilots according to the "higher-educational institution (theoretical training for the second level of higher education with the awarding of a bachelor of science degree)—flight school (assimilation of training aircraft)—UATs (flight training on a combat aircraft)" model. Such fundamental changes, however, are possible only provided the programs providing comprehensive support of the training process are realized, and first and foremost positive social changes in the life and status of the officer in society.

The number of training institutions will be reduced by two or three times under conditions of a sharp reduction in the quantity of aviation personnel needed for all branches of the armed forces. The further development of higher educational aviation science, improvement of the training process with a regard for the optimization of the mix of military-educational institutions, coordination of work among them and accomplishment of a transition to the training of aviation personnel under contract all become topical in this regard. That is unfortunately still difficult to achieve. A program to develop the physical plant of the higher-educational institutions, called upon to be the foundation for intensifying the training process, has yet to be approved, for example.

The absence of a long-term program for the development of the higher-educational institutions during the period of cutbacks in the Air Forces could cost us dearly in the near future. The situation is aggravated by the fact that many of the officials on whom the making of decisions depends, either owing to a lack of time or frequently even desire and patience to get to the heart of the problem, are not receptive to the idea of pursuing profound reform of education at the educational institutions of the Air Forces. They are misinforming the leadership of the Air Forces and the Ministry of Defense, without looking at the heart of the matter, with their incompetent and superficial judgments, and are impeding the adoption of progressive programs for the development of the higher-educational institutions and the training of cadres.

I am not laying it on too thick. A real threat has arisen not only of the disruption of educational reform at Air Forces higher-educational institutions, but also their ability to train the necessary quantity of highly skilled aviation specialists in the future as well. The guarantee of the fact that mistakes will not be made in reorganizing the military-educational institutions and pursuing the reform of education are the comprehensive and public discussion and affirmation of the conceptual framework for the development of the higher-educational institutions and the adoption of promising long-term programs for them. The leadership of the branches of the armed forces, without repudiating in general the idea of uniting the aviation schools, are in fact slowing up the reforms. This is also being facilitated by the latest "reforms." Two of our helicopter schools have thus been transferred to the ground forces. But the Air Forces continue to train the aviation engineers and technicians, specialists in rear support, communications and pilots in transport aviation for those same ground forces, and they in turn train helicopter pilots for the Air Forces and other branches of the armed forces. The same situation has also taken shape in the "mutual relations"

of the Air Forces with the PVO [Air-Defense Troops] and the Navy. Everything is mixed up. The artificial disunification of kindred educational institutions is having a negative effect as a whole on the development and improvement of the scientific-methodological work of the higher-educational institutions and the training of professors, instructors and the future pilots. The need for training institutions as part of the Ministry of Defense of the Russian Federation is increasing, owing to the impossibility of ensuring the optimal utilization for the Air Forces higher-educational institutions under conditions of redundancy in the training of aviation specialists by the branches of the armed forces, which leads to an increase in expenditures for training.

It has become obvious by now that one cannot do everything in a day. Work is needed in the future to improve the system of training of aviation cadres, change the supervisory style of the military-educational institutions and coordinate scientific-methodological work inside their walls. These tasks can be accomplished only through joint efforts. So what is the matter?!

Techniques Used in Accident Investigations Described

93UM0679B Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 2, Feb 93 (signed to press 9 Feb 92) pp 4-5

[Article by USSR State Prize Laureate Candidate of Technical Sciences Colonel Yu. Korovkin under the rubric "Flight Safety: Investigation of Flights Accidents": "A Failure 'Leaves Tracks'"]

[Text] *Materials will be published under this rubric on the methodological techniques employed when investigating a flight accident [LP].*

It is necessary to determine in any flight accident whether it was a failure of the hardware in flight; if so, then why? It is exceedingly difficult, however, to ascertain the causes for the appearance and development of a failure from the misshapen and charred fragments of an accident or crash, since they are subject to additional influences.

The kinetic energy that an airframe possesses when encountering an obstacle is realized over a very short time interval, analogous to an explosion, which smashes structural elements into small fragments and scatters them across a considerable distance. This effect is magnified by the destruction of systems and units operating under high pressures using gases and liquids, the actuation of pyrotechnic materials and ammunition, the escape of liquid or gaseous oxygen and the like. The fire that arises after the ignition of the fuel, the mass of which is 30—50 percent of the takeoff mass of a contemporary aircraft, also causes considerable damage.

Establishing the true causes for an LP is moreover an exceedingly responsible matter, since decisions are made according to the results of the study that entail millions in spending, for example to improve production or structural elements of the airframe, refine operational processes, make changes in the organization and techniques for personnel training and perform preventive measures.

A system of methods and means of researching objects from accidents (hereinafter the system)—for the development of which the originators were awarded a USSR State Prize—was created at the NII [Scientific-Research Institute] for the Operation and Repair of Aviation Hardware [AT] in order to ascertain the causes of failures in an operative manner. The merits of this system are that it makes it possible to conduct research under conditions where:

—the parts and assemblies of the aircraft, on-board recording devices etc. used as sources of information to establish the causes of the failure have sustained significant damage or destruction;

—the information remaining at the disposal of specialists is in many cases preserved only in the form of microscopic traces;

—the functional ties between individual elements of the aircraft system have been destroyed, and often some of them cannot be found at the scene of the accident (owing to complete destruction, burning, landing in a body of water etc.);

—the failed unit that led to the accident exists in a single copy;

—the aircraft systems have differing functional principles (from mechanical to electronic);

—the resolution of issues pertaining to various fields of science (from mathematics to criminology) is required in the course of the research, and a considerable portion of the research is being conducted under field conditions right at the scene of the LP;

—all of the work is performed within a certain time frame.

The system is based on certain common and frequent scientific principles that take into account the specific nature of studying aircraft accident sites. The most important of those—ensuring the trustworthiness of the results—is achieved through the use of a host of traits and methods founded on various principles of physics for the accomplishment of a single task, the most complete possible reconstruction of information that was distorted as a result of the effects of destructive factors, the documentation of all of the results obtained in the process of research, the strict determination of the sequence of events, ruling out mistakes that could lead to the loss of information about a failure, and a combination of methods of analysis and synthesis when studying the phenomena.

Chief among the methods of obtaining and employing information on the process of development of an accident situation are those that provide for the use of the flight data-recording equipment (SOK), and especially on-board recording devices (BUR). The effective utilization of flight information when investigating a flight accident is made more difficult (in roughly 30 percent of LPs), however, by its partial or complete loss. Methods of reconstructing and obtaining information from damaged media (both optical and magnetic) have thus been developed, and are widely utilized, in connection with this.

It should be noted that the BUR (even in cases where they are physically intact in an LP) carry information about changes in a limited number of parameters of the flight and operation of the hardware. Research on the state of the aircraft must therefore be performed and the place where it came down studied in order to evaluate the operability of aircraft systems, localize the failure and establish its causes. A whole set of methods, founded on various principles of physics and engineering and taking into account the "materiality" of traces in parts and the terrain in aviation hardware failures, is used for that purpose. The general laws for the formation of these "informative" traces in the downed aircraft have been determined and methods and techniques have been developed that make it possible to ascertain them in the fragments of an airframe and "force" them to "talk."

It is possible to determine from the traces on the parts the conditions of their destruction (in flight or upon impact with an obstacle). It has been established, for example, that the following characteristics of the state of the AT can be reflected in those traces in an impact with an obstacle:

—the kinetic energy of spinning rotors (aviation engines, generators, pumps and the like);

—the pressure of working media (liquids, gases) and their mass and volume in aircraft systems;

—the position of controls, elements of automatic equipment, instruments and indicators;

—the presence (or absence) of residual magnetization of a certain level;

—the degree of heating of the parts.

Mathematical and physical modeling (part-scale and full-scale) of the dynamics of flight and the trajectory of movement of the airframe are widely used in the course of investigating an LP on the basis of information from the flight data-recording equipment. Modeling is employed in those cases where the information from the BUR and the data obtained on the state of the aircraft wreckage are insufficient to determine the causes of hardware failure. It is performed with the aim of establishing:

—the possibility and duration of the development of the damage ascertained in a part in the failure of a unit or assembly;

—the types of flaws that led to a failure recorded in flight;

—the actual conditions of the operation of the part, as well as the boundary conditions at which the ascertained flaw arises;

—the correspondence of the damage existing on the parts to a certain (operable or inoperable) state of the assembly;

—the sequence of the destruction of parts;

—the possibility of the practical realization of the stated hypotheses on the causes for the appearance of the failure.

In order to formulate a conclusion, we turn to methods that provide for the logical processing of the primary information, as well as analysis and synthesis of the data gathered at all stages of the investigation of the LP. I would like to single out among those the method of structuring a diagram of the cause-and-effect links. Standard flowcharts are used as the foundation, and are then clarified and supplemented in the course of the investigation of a specific LP. The structuring is performed by stages—from a known final consequence, obtained from an analysis of the circumstances of the LP and information from the SOK, to its primary cause.

Technical gear, both special gear and some used in other areas of science and technology, has been developed and is employed to investigate aircraft wreckage. Flying laboratories equipped with all of the necessary equipment for working under field conditions are of especially great significance.

This system provides for the quite complete performance of the tasks that arise at all stages of the investigation of an LP. Its effectiveness is characterized by the fact that the concrete cause of the failure is found in 50 percent of the cases, it is established that there was no failure in 40 percent of the cases, and only in 10 percent of the cases is a cause not found (likely or possible causes are indicated).

It must be noted in conclusion that one feature of improving the system of methods for investigating crashed aircraft is its ever greater algorithmization, thanks to which the necessary preconditions are created for a fundamentally new stage—the adoption of expert systems (ES) into the practice of investigating flight accidents. These are distinguished by the fact that they are oriented toward resolving a broad range of tasks in areas that were not formalized before, which were felt to be little accessible to the use of computers.

The specialists using ESs in the course of investigating an LP can surpass the capabilities of experts in that realm. This would make it possible to expand the circle of issues

they resolve by accumulating the knowledge of highly qualified experts in the ESs.

All of the agencies concerned must be brought into the creation of ESs (coordination of the algorithms for identifying *a priori* information, entered into the system and used in the future to determine the causes of failures in automated mode). This will facilitate a rise in the objectivity of the evaluations, and will make it possible to come to a unified opinion in the course of a specific LP investigation on questions of the traits and nature of the development of AT failures and, consequently, its causes as well, and to take effective and coordinated steps to prevent LPs and increase the safety of flights.

Algorithm for Situation Assessment in Airborne Command and Control

93UM0679C Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 2, Feb 93 (signed to press 9 Feb 92) pp 6-7

[Article by Candidate of Military Sciences Colonel (Reserve) V. Babich under the rubric "Combat Training: Experience, Problems, Opinions": "Artificial Intelligence at the Service of the Pilot"; conclusion—for previous parts see Nos. 10—12, 1992 and No. 1, 1993]

[Text]

4. The Chief Expert—The Commander

Analysis of the combat losses of aviation by opposing sides in armed conflicts that differ in scale makes it possible, in my opinion, to uncover more fully the nature and determine the priority ranking of errors that are made by pilots in the air when performing missions. If we trace how fighter aviation was used in World War II, we can reveal the following causes of such errors: insufficient circumspection in battle, numerical supremacy of the enemy, disruption of the interaction between crews in a group, the use of ineffective maneuvers in a dogfight and the lack of suitable command and control of the battle...

We will consider the last cause in more detail.

The foundation of the command and control of subordinates in the course of combat operations, as is well known, is the plan of the air commander, which he makes on the basis of a clarification of the combat mission, conclusions from an evaluation of the situation and calculations performed. We would note that all of this takes place on the ground. But what about in the air, with an unexpected change in the situation, when the commander has turned over virtually all of the functions of getting information about the enemy to the hardware entrusted to him, and most often receiving just meager information from it? Only a wealth of combat experience, to all appearances, could help him to grasp the developing situation and predict its continuation. But unfortunately far from all have enough experience, and the training process will moreover not be able to make up for these gaps in training.

So then who today receives the right to make the decision to enter into battle?

If we are talking about a rank-and-file pilot, then he rarely enjoys that right, as before—only in the course of an intercept of a solitary airborne target. It is appropriate here to recall the experience of the recent war in the Persian Gulf, where solo sorties were not recorded at all, even though the aviation was operating primarily at night. The flight (four aircraft in tactical aviation and three in strategic) was the tactical entity entrusted with the fulfillment of independent missions. Group battles and strikes constituted the foundation for the employment of aviation, while organizing the interaction among crews remained the primary concern of the flight commander.

Specialists have noted that even the crews of the AWACS and EW aircraft coordinated operations not only among themselves, but also with a detail for their direct coverage—a pair or a flight of fighters. A Hawkeye airborne command post, an EC-130 EW aircraft and four F-15C aircraft as an aggregate, for example, represented a dynamic system with controlling and controlled objects and uniform channels for communications and information exchange among them, with an informative nature "upward" and a command nature "downward." The effectiveness of the functioning of the system with feedback was evaluated depending on the duration of the command-and-control cycle.

Foreign specialists also include the flight of fighters, "encircled by an external environment with various threats," among similar dynamic systems, based on the experience of local wars. The crews experienced particular stress in combat operations when protecting the aircraft of strike groups, and concretely in those situations where the enemy, making use of camouflage and military cunning, selected the most favorable moment for attack.

The proposal to utilize the variation of first takeoff, and then the posing of the concrete task, was adopted as the standard one, taking this circumstance into account. The commander was forced to perform such labor-intensive processes as evaluating the situation, analyzing the possible options for action and planning the battle right in the course of the flight, simultaneously devoting the lion's share of his attention to piloting the aircraft.

The scarcity of time for the mental work of the pilot, as has already been emphasized, brought about the necessity of creating on-board expert systems. It was, however, not difficult to assume that the "electronic assistant" should function in different ways in those cases where a dialogue is conducted with it by, for example, a rank-and-file pilot or the leader of a flight: the former, after all, is controlling just an aircraft and its weapons, while the latter, aside from that, is also controlling subordinate

crews. The latter is moreover also obliged—and this is one of his chief tasks—to turn the four fighters into a powerful combat entity able to win a victory in group battle. Specialists have determined that the commander, in order to achieve that aim, should make a so-called organizational decision, after assessing the situation, based on the competent disposition of forces before battle and the efficient distribution of functions among the crews.

What do those functions consist of apropos of the actual conditions of the group combat flight?

The aircraft flight formation, to the extent of the development of aircraft technology and armaments along with the growth in the combat potential of fighters, was opened up to such intervals and distances that at first provided for the preservation of visual contact among the crews, and then became commensurate with the distance for launching air-to-air guided missiles with semi-active radar homing heads. Visual contact among pilots was broken off as a result.

The command and control of subordinates that you cannot see is a difficulty that was experienced to the full by the pilots who took part in the armed conflicts in the Near East at the end of the 1960s and beginning of the 1970s. The enemy, along with everything else, was constantly jamming the sole channel for information exchange among the crews—radio communications. Under such a variation, at the threshold of the development of fighter aviation called "go out separately, but fight together," the functioning of a dynamic system with a large number of objects under command and control became simply ineffective. One aircraft was then dropped from the flight of four fighters. The three-element structure proved to be more suited to waging all-aspect battle, the "crux" of which was considered to be a missile attack on straight-on headings.

This step led to an appreciable change in the redistribution of functions among the crews in the course of aerial battle. The departure from the principle of "shield and sword" (one covers and the other attacks) entailed the rejection of mutual coverage of fighters. Completely new tasks—decoy operations, the performance of break-off, back-up or free maneuvers (augmentation of efforts)—were designated at the same time. It was only necessary to distribute them correctly among the controlling and controlled objects (the function of "sword"—the "strike aircraft"—was preserved).

The commander of the threesome automatically became the "strike" aircraft while supervising the two subordinate crews, which were delegated other functions than his. When a flight used to go up in full complement (four) in a single tactical entity with its own definite mission, a pair of aircraft was formed. The crews, having received a specific combat assignment, operated not spontaneously but rather in accordance with a plan developed earlier. A strike against the enemy, which was then augmented, was made according to the rules that were discussed earlier (AVIATSIYA I KOSMONAVTIKA, 1993, No. 1) after the decoy operations. The "free-maneuver" group (or aircraft) operated at that moment "according to the situation," ready at any moment to assist a crew that got into a difficult situation.

Some fighter pilots have in recent years unfortunately begun to forget such a crucial stage of the preparation for flight as the development of a plan for the impending battle. The reason for this is the widespread opinion that only improvisation is characteristic of the true master. The experience of both the recent and the now-distant past forces us to approach an evaluation of the professionalism of the pilot today, and especially the leader of a group, with different standards. Today he should be not only an excellent pilot and shooter able to lead a four-aircraft element, but also be recognized as a leader able to evaluate and predict a complex situation, plan group battle, organize interaction in the air and independently make comprehensively well-founded decisions on the application of the forces subordinate to him.

It would not be superfluous in this regard to refer to the Manual of Combat Operations of U.S. Tactical Aviation, which says that "Leadership in battle is a talent that should be recognized at all levels. Individuals able to lead subordinates in the air must be noticed in timely fashion and promoted. The talent of the commander is usually manifested in the course of warfare, but the ability to think and reason intelligently is acquired beforehand."

The crisis in the sphere of the mental activity of the pilot has forced the aviation command in the United States to take the path of training pilots in the skills of "intelligent reasoning" in duels with an active "enemy." Each tactical-aviation squadron, as is well known, takes part every year and a half in the Red Flag exercises at the Nellis test range, specially equipped for the purpose. More than a hundred simulated PVO [air-defense] assets and an "aggressor" squadron operate in complete accordance with the tactics of a likely adversary, not "playing along" with the trainees. The pilots can receive a "homework assignment"—refine poorly mastered elements of weapons delivery—after the completion of the exercises and analysis of the results (chiefly the "losses").

The white heat of training of the mind weakens appreciably at "home," however, since the principal impetus to pose tactical riddles to the pilot—the "enemy"—is lacking. The standard-issue simulator equipment available at each air base is little help in the development of tactical thinking among the pilots, since it by and large facilitates only their acquisition of motor skills in operations in a concrete situation.

American specialists feel that it is essential, first and foremost, to fill in the vacuum between the expense and complexity of the training process, on the one hand, and its simplicity, on the other, in order to achieve even an inconsiderable rise in the intellectual level of the pilot. They feel it mandatory in this regard to put the trainee

into an operating mock-up of the cockpit of a combat aircraft—it would suffice to put the moving situation being evaluated by the pilot onto a special desktop screen that is analogous to the display inside the cockpit.

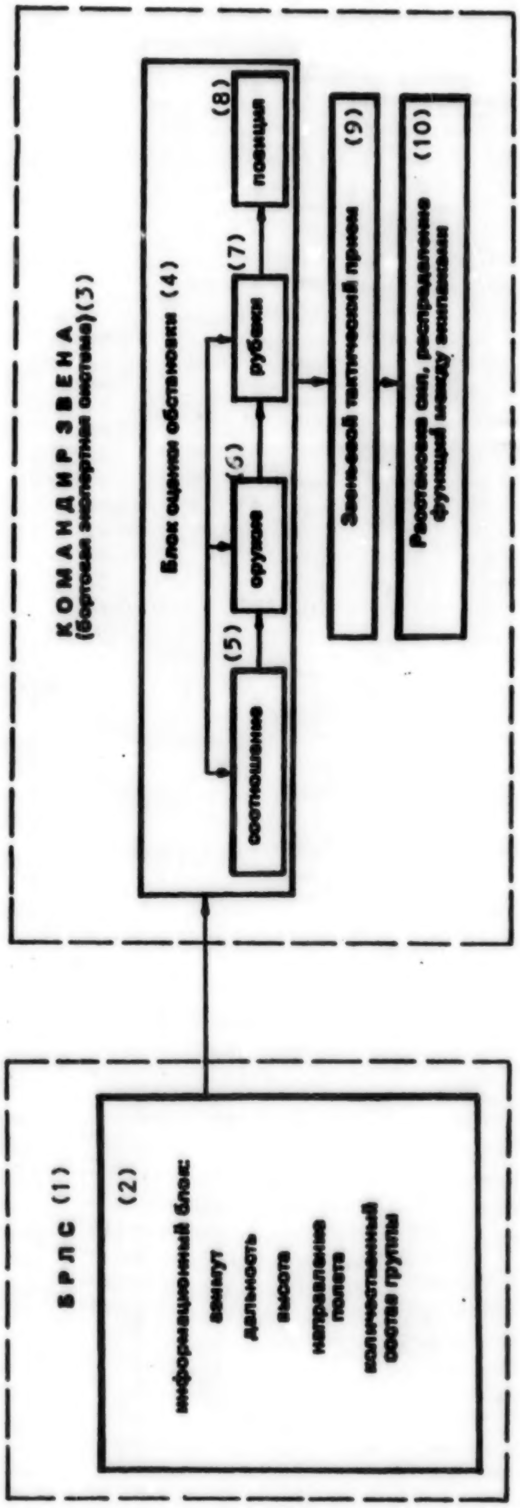
Several "desks" with such screens have been installed in an already operating system for training flight personnel in the evaluation of a situation and making tactical decisions. The aerial situation is simulated on the screen in the form of aircraft blips ("own" and "enemy") by the supervisor of the classes, who can where necessary break off a flight and even "take a step backward" for the extemporaneous investigation of erroneous decisions.

The important conclusion was drawn, according to the results of the first simulations, that they were none other than a continuation of the training process of the likely adversary and the concluding stage of the mathematical modeling in the course of which the logical framework of the battle is formulated. The exercise using full-scale modeling is in turn defined in the course of the flight experiment, and only after its completion are recommendations issued for the practical assimilation of tactical innovations by flight personnel.

A study of the experience of fighter operations in real battles and semi-full and full-scale modeling has made it possible for me to develop a very simple algorithm of the resolution of a task according to an analysis of the situation by a flight commander (see diagram). This process, in my opinion, should begin from the moment when the group target has been detected, and its azimuth, range, speed, altitude and direction of flight, as well as the numerical composition, determined.

Block one—"correlation." It is felt that the flight should enter battle with forces equal to the enemy. A numerical inequality of forces could be established after identification of the specific situation, however. Then the model of battle "in the majority" or "in the minority" takes effect.

Algorithm of Situation Assessment



Key:
1. BRLS
2. information block: azimuth, range, altitude, direction of flight and numerical composition of group
3. Flight commander (or on-board expert system)
4. situation assessment block
5. correlation
6. weaponry
7. points
8. position
9. flight tactics
10. disposition of forces, distribution of functions among crews

Block two—"weaponry." The fighters could prove to be in a situation where they have a "surplus" or "shortfall" of firepower; that is, there are greater or lesser areas of effective engagement for the on-board weaponry than the enemy. An advantage in firepower makes it possible to compensate for shortfalls in "quantity."

Block three—"points." The point of engagement at which the fighters should arrive strictly on time is designated when performing the task of covering strike groups. This cannot always be accomplished, however, under the rapidly changing conditions of contemporary battle. Any skirting maneuvers, most naturally, are ruled out in the event of lateness, for instance, and there remains just one chance for victory—a frontal strike (head-on battle). The "weaponry" moves to the forefront in such a situation—greater permitted launch ranges of missiles should compensate in full for lateness and have an effect on the configuration of the disposition of forces before the start of an attack. The precise or early arrival at an assigned point brings about the necessity of employing some tactical maneuvers ("claw" or "dragon").

Block four—"position." After reaching the point of engagement, the flight could prove to be at too small or too large a heading angle in relation to the enemy for a reliable attack, and higher or lower than the target. The flight commander, proceeding from tactical considerations and with a regard for the maneuverability of the aircraft as well as the destructive capabilities of his weaponry, should determine the most advantageous position for the performance of a standard method of attack by the flight. It should be emphasized that "one's own" methods and combat formations correspond to each position.

It is not difficult to note that the proposed algorithm is nothing more than the simplest model for the resolution of a tactical task. It could be made more detailed and supplemented with blocks at that or a lower level. It is proposed that readers, and especially flight commanders, do so.

Method Proposed for Evaluating Utilization of Aircraft Service Life

93UM0679D Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 2, Feb 93 (signed to press 9 Feb 92) pp 8-9

[Article by Lieutenant-Colonel A. Bekhter and Candidate of Technical Sciences Colonel (Retired) V. Lavrik under the rubric "IAS: Solution to a Problem Proposed": "Loss of Service Life Could Be Avoided"]

[Text] *It is well known that the utilization of aircraft equipment for its intended purposes is limited by its service lives (in hours, landings, actuation cycles and the like) and the stipulated overall time of service. The aggregate of these values describes the operability reserves of the hardware and its service-life potential. It may be realized—that is, turned into flying time—at a fully defined rate of operation, which is defined by the ratio of the service life and its corresponding time of service. Losses are inevitable at a lower rate of operation. This potential, taking into account hardware that is in storage, makes it possible to have, for instance, yearly flying time of 300—400 hours per aircraft in frontal aviation. The aircraft often actually fly about 100 hours, and the pilots 50—70, in a year. A small number of aircraft engines and assemblies moreover come in for repairs without a fully utilized service life, owing to the expiration of the overall time of service. What is the reason for that? First and foremost, of course, the decreased appropriations for defense and shortages of engineering and technical personnel, fuel and spare parts. But also the complexity, increased many times over under these conditions, of the tasks of command and control, requiring a systematic assessment of the factors affecting the rate of operation. The discussion here concerns new approaches to performing that assessment, making it possible to increase the effectiveness of the utilization of service-life potential.*

It seems at first glance that if the overall flying time of an aircraft is counted in hours, then there should be no fundamental difference between flying time and calendar time of service, and the reliability of the hardware could be assessed using either of those values. But that is not so. The extent of corrosion, aging and biological damage to the airframe depends on the calendar duration of operation, while overall flying time characterizes the operation of the hardware and its wear and tear and fatigue damage accordingly. A criterion that takes into account both accrued run time and time of service is thus necessary for a complete accounting of the whole spectrum of demands in effect. Since the aviation hardware is employed with interruptions, the extent of realization of the service life within the limits of a certain period of calendar time can be described by the average daily rate of its expenditure.

The time of service (T) of an aircraft may be represented as the sum of the times of pre-operational storage (T_{st}) and actual operation. Expressing the latter in terms of service life as measured in accrued time in hours (τ) and the average daily rate of its expenditure (η), we have:

$$T = T_{st} + (\tau/365\eta), \text{ years (1)}$$

We will put equation (1) into a form convenient for analysis:

$$\tau = (T - T_{st})365\eta, \text{ hours (2)}$$

Whence it can be seen that an increased rate of service-life expenditure is necessary to provide one and the same accrued operating time when the storage time is increased. Two causes of losses are thus possible—owing to a low rate of expenditure of the service life, and owing to increased duration of pre-operational storage.

For example, where $\tau = 2{,}000$ hours, $T = 10$ years, $\eta = 0.3$ hours/day and $T_{st} = 2$ years, the service-life losses are 56

percent. They decrease with increases in the rate of operation, and rise with increases in the duration of pre-operational storage. If we take the storage period in the previous example as being equal to five years, the losses exceed 70 percent.

The losses increase, at an unchanged rate of operation, with increases in the storage time. They can be reduced by extending the time of service, but at low values for η an increase in the time of service provides an insignificant gain. Where T is increased to three years and η has the same value (0.3 hours/day), the losses decrease from 56 to 40 percent. A lengthening of the time of service can therefore be justified only with a sufficiently high average daily rate of expenditure of the service life.

How can losses of service life be avoided? An answer may be obtained by solving equation (2) for η. If a guaranteed running time τ_g for an aircraft engine is 2,000 hours, for example, and it was stored for three years before the start of operation (before expiration of the effective term of storage) with a guaranteed time of service T_g of 10 years, the required average rate of expenditure of the service life should not be less than 0.78 hours/day; that is, the annual accrued running time should not be less than 285 hours.

We would note that this methodological approach could also be extended to the case of the storage of items in a non-mothballed state on board an airframe, with their occasional testing under standard servicing procedures. If the item is a removable one and the testing is performed in the interests of ensuring its readiness for utilization, however, it must be taken into account that some of the service life will have been expended even before the start of operation.

We will consider a more general case. We will assess the rate of expenditure of the service life of an airframe within the context of a whole operational cycle, with a regard for the hardware being in various states (use for its intended purpose, maintenance and restoration of operability, waiting in good working order, storage). The duration in each of them describes one of the operating properties of the airframe (failure-free operation, maintainability, operational feasibility, longevity) with a regard for the level of perfection of maintenance (TO) and logistical support (MTO), while the rate of expenditure of the service life reflects the manifestation of those properties as a whole. This value at the same time acts as an indication of the productivity of the airframe (in the form of flying time, for example, or the number of aircraft-sorties per unit time).

The rate of expenditure of service life (K) in such a representation serves as a criterion of the operational technical quality:

$$K = (T_t/(T_t + t_r + t_{pl} + t_{wm} + t_{wls}))K_{year}, \quad (3)$$

where $T_t/(T_t$, t_r, t_{pl}, t_{wm} and t_{wls} are the cumulative amounts of time the airframe is in flight, undergoing restoration of an operable state, planned maintenance, waiting for maintenance (airframe idle time for organizational reasons) and waiting for logistical support (idle time waiting for spare parts) over the span of a certain operating period, and K_{year} is the work time utilization factor.

The value T_t is a measure of the usefulness of an airframe, and describes its failure-free operation. The duration of restoration (t_r) and planned maintenance (t_{pl}) reflects the expenditures of time to find and eliminate defects and maintain operability, and describes the maintainability of the airframe. One may judge the level of perfection of the TO and MTO by the values t_{wm} and t_{wls} respectively. The work time utilization factor K_{year} shows what share of the year's time is relegated to the operation of the airframe, and what share to idle time during non-working time. $K_{year} = 1$, for example, with around-the-clock work on the hardware. $K_{year} = 0.237$ with an eight-hour work day and a 42-hour work week (yearly work time reserve equal to 2,080 hours).

The following group of summary indicators, consistently revealing the effects of the characteristics described on the rate of service life expenditure, can be singled out from expression (3).

1. Where $t_{pl} = t_{wm} = t_{wls} = 0$ and $K_{year} = 1$, we obtain an indicator of reliability that takes into account the joint manifestation of the absence of failures and maintainability (K1).
2. Where $t_{wm} = t_{pl} = 0$ and $K_{year} = 1$, we calculate the summary indicator of reliability and operational feasibility (K2). It reflects the likelihood of the airframe being in an operable state under conditions of idle time only for planned and unplanned maintenance.
3. Where $t_{pl} = 0$ and $K_{year} = 1$, we obtain an indicator that also takes into account the effects of the characteristics of the actual system of maintenance on the operational technical quality of the airframe (K3).
4. Where $K_{year} = 1$ and all values in the denominator are not equal to zero, the effects of the system of logistical support are taken into account (K4).
5. Under the latter (paragraph 4) conditions but where $K_{year} < 1$, we also obtain the idle time of the airframe in non-work time (K5).

The indicators K1—K5 thus make it possible to calculate the rate of expenditure of airframe service life with a regard for its operational level, organization of operations on the equipment and the quality of the functioning of the system to supply spare parts. The unit of these indicators is an hour of flying time per hour of operation. By multiplying the value of K by the duration of the year in hours, we obtain the available yearly flying time of the airframe (T_a). We would note that the required value of the yearly flying time (T_{req}) for the complete consumption of the service life (R_r) is equal to the ratio of that service life to the corresponding time of service.

The methodological approach set forth provides an opportunity to move to a determination of the value of the service-life potential of an airframe that could be realized over a designated span of time of service—that is, to an assessment of the attained rate of expenditure of the service-life potential of an airframe and its juxtaposition with the required one. That will now make it possible to predict the using up of the service-life potential and, where necessary, to make the corresponding corrections in the organization of IAS [aviation engineering service] operations based on a regard for the effects of the determining factors.

We will consider an example of such an assessment. Table 1 presents the initial data, and Table 2 the results, for a comparison of two fighter aircraft, the domestic Su-27 and the F-15 of the U.S. Air Force.[1]

Table 1

	Type:	
	Su-27	F-15
T_t, hours	5.9	4.12
t_r, hours	3.4	3.23
t_{pl}, hours	7.1	1.12
t_{wm}, hours	2.95	5.44
t_{wls}, hours	31.3	5.1
K_{year}	0.24	0.31
R_r, hours	4,000	6,000
T_{req}, years	25	10

Table 2

	Type:	
	Su-27	F-15
K1	0.63	0.56
K2	0.36	0.49
K3	0.31	0.30
K4	0.12	0.22
K5	0.028	0.067
T_a, hours/year	245	587
T_{req}, hours/year	160	600

The comparison shows that in operational suitability within the context of TO systems (under K3), the aircraft are roughly identical, with the domestic one better in reliability (K1) but inferior to the foreign in reliability and maintainability (K2) taken together. The F-15 has the higher quality level when the lesser idle time waiting for spare parts (K4) and increased value for K_{year} (K5) are taken into account. The attained value for K5 allows the Su-27 to serve out its service life without losses (it has $T_a > T_{req}$). It is easy to estimate that the losses of service life for the foreign model are about five percent, despite the fact that it is operated more intensively than the domestic one ($K_{year} = 0.31$).

The necessary reduction in idle time of the airframe for TO can be determined for the complete using up of the service life, and the corresponding measures developed with a regard for expenditures, according to the data cited.

An analysis of operational suitability based on an assessment of the rate of expenditure of the service-life potential when putting new airframes into service is of particular significance. It is known that the technology for servicing and the organization of technical operations depends on the design features of the airframe as determined by its dedicated purpose and the quality of design engineering and production. By possessing data on the airframe and varying the requirements and their limitations, it is possible to substantiate the most acceptable variation, from the time standpoint, for technical operation and logistical support with a regard for the shortage of material and human resources.

We turn our attention to another exceedingly important sphere of the possible application of such an analysis—the certification of product and production processes. Any product is valued markedly higher if it and the processes of its manufacture have a certificate of conformity—a document indicating that the given product and production are in accordance with certain requirements (standard, for instance).

While the flight quality of an airframe is evaluated for conformity to the Uniform Standards of Airworthiness, the assessment of the level of operational excellence requires its comparison with competitive models of aircraft in the given class. The proposed approach provides that opportunity when determining the competitiveness of an airframe and substantiating its price for both the domestic and foreign markets.

We have thus demonstrated that a sufficiently correct solution can be obtained for a whole series of tasks—such as determining the pattern of time expenditures for operations, predicting losses of service life and developing measures aimed at averting those losses and assessing the operational technical quality of airframes in service and under development with a regard for organizational, technical, economic and other factors and the certification of aviation hardware—on the basis of an analysis of the rate of expenditure of the service life of aviation hardware (service-life potential). The use of the results obtained makes it possible to increase the economic efficiency of aircraft operations virtually without any additional material expenditures, which is particularly important at the current time.

Footnote

1. The initial data for the Su-27 were obtained according to the results of the initial operating period of that fighter in a military unit. The indicators for the F-15 aircraft describe it with a regard for various periods of operations and base areas.

New MiG-29M Multirole Version of MiG-29 Described

93UM0679E Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 2, Feb 93 (signed to press 9 Feb 92) pp 16-18, 32

[Article by A. Velovich under the rubric "Domestic Aviation Hardware": "The MiG-29M—A Familiar Stranger"]

[Text] *The MiG-29 is well known in our country and abroad, and is by rights the pride of the Air Forces and the Design Bureau imeni A.I. Mikoyan, where it was created. The improvement and development of this aircraft is continuing in accordance with the requirements of the times; the latest version is the MiG-29M. The British aviation magazine FLIGHT INTERNATIONAL called this MiG "the supreme weapon of Russia" in analyzing its characteristics.*

The new MiG-29M fighter was displayed for the first time in September of 1992 at the international air show at Farnborough, not far from London. It differs little from series-produced versions in outward appearance, but that impression is deceiving. It is deserving of a new designation—the MiG-33—in the opinion of many specialists. General Designer R. Belyakov, however, feels that this addition to the MiG family will receive official recognition and its own new name only upon the completion of state joint testing.

The geometric dimensions of the fighter have remained as before, but the design of the airframe has undergone substantial changes. Upper outlets for the air intakes are lacking, first and foremost. The protection of the engine against the ingestion of foreign objects is now ensured by a protective grill mounted in the duct. This device is analogous to that employed on the Su-27, but has a number of differences as well that, in the words of aircraft chief designer M. Valdenberg, have provided for the reliable protection of the protective grill against icing. The new device was subjected to forced verification during flight testing—a duck got into one of the air intakes during takeoff. The grill only sagged slightly, but the engine sustained no damage whatsoever.

The configuration of the wing strakes has been altered—they now have a sharp edge. This provides for the more energetic shaping of the vortex system at large angles of attack and, as a result of that and ailerons with increased span, for a marked improvement in controllability at low speeds.

The MiG-29 fighter has been demonstrated abroad repeatedly over the last several years, and one of the most frequently asked questions of the representatives of the firm was, "So why doesn't the aircraft have a fly-by-wire control system (SDU)?" The reason for that is the adherence of the OKB [Experimental Design Bureau] to the most reliable and proven engineering ideas. An SDU was installed on the MiG-29M, but the designers again used an approach that guaranteed reliability: an analog system with four-way back-up was used in the longitudinal channel, the redundancy is three-fold in the heading and roll channels, with one of the control loops moreover using mechanical wire, providing for the setting of the ailerons and rudder to half their full settings.

M. Valdenberg also substantiates the use of an analog rather than a digital SDU: "I am convinced that this was the correct decision, since it provides for greater safety and less likelihood of any unpleasant surprises. That is even though the analog SDU is more complicated and loses out in weight compared to a digital one." One can agree with the chief designer, especially if one recalls the recent accidents of the SAAB JAS-39 Gripen in Sweden and the YF-22 in the United States. The cause of both of those flight accidents was insufficient software support for the digital SDUs of those fighters. The case of the loss of a Tornado fighter/bomber of the German Air Force owing to the failure of the digital SDU under exposure to the electromagnetic field of the powerful transmitting antenna of a radio broadcasting station is also well known.

An increased-area stabilizer with a "tooth" on the leading edge has also been installed on the aircraft to increase the effectiveness of the control system. The "tooth" improves the flow pattern at large angles of stabilizer settings.

One of the noticeable outward differences of the MiG-29M from the prior model is the absence of fences running from the base of the rudders along the upper surface of the wings. They were used on the MiG-29 to house the thermal decoy target and chaff firing devices. This device is located under a fairing on the upper surface of the fuselage on the latest model.

There is an air brake of large area (more than one square meter) located behind the cockpit. The longitudinal moment that arises when setting the panel is countered automatically by the SDU. One braking chute with an area of 17 m^2 has been replaced with two of 13 m^2 each. The reinforced landing gear, designed for the maximum takeoff weight, has a brake with enhanced power, which reduces the length of the runout.

The forward portion of the fuselage, of welded design, is made of aluminum-lithium alloy. This has provided a sharp reduction in weight, since there is no need to make the joints airtight in the fuel tank/compartments or cockpit, there are no overlaps for riveting and the unit mass has been reduced. There is another advantage to this design—the complete utilization of internal spaces to hold fuel. This could not be done in a rivet-fastened design, owing to the impossibility of making all of the rivet seams airtight.

Composite materials are widely used on the MiG-29M, as on the MiG-29. The air brakes, engine cowlings, air-intake ducts and rudders are made of them. The

design of most of the enumerated elements is composite-honeycomb, which markedly reduces the weight and provides quite high rigidity.

The fundamentally new design and the additional internal volume freed up after the elimination of the upper intakes has made it possible to increase the fuel reserves by 1,500 *l*, bringing them to 5,700 *l*. The flight range at cruising speed and altitude has been increased from 1,500 to 2,000 km. Three external fuel tanks (a center tank with a capacity of 1,500 *l* and two wing tanks with 1,150 *l* each) provide a ferry range of 3,200 km. Many pilots in line units have repeatedly pointed out the desirability of increasing the operating range of the MiG-29. The designers took those wishes into account in the new model. The longitudinal instability of the aircraft and the use of an SDU have also facilitated an increase in range, in view of the decrease in balance losses in cruising mode.

The principal tactical-performance data typifying the maneuverability (sustained positive G forces in a banked turn, rate of climb, acceleration time) for the MiG-29M have remained at the prior level, but one improvement was the marked increase in the allowable angles of attack and, as a consequence of that, the available G forces for non-sustained maneuvers.

The new fighter has a limiter of maximum modes that does not permit it to go beyond a set angle of attack. The maximum value in testing was set at 30°, but M. Valdenberg feels that the "bar" will be raised upon the completion of testing. R. Belyakov describes the MiG-29M thus: "This is the best aircraft in the world overall from the standpoint of overcoming stalling and spins. The MiG-29 had already been brought to a high level, and we have gone even further with the MiG-29M."

The RD-33K engines have thrust with afterburners of 8,800 kgf, which is 500 kgf more than the series-produced RD-33 engines. The letter K signifies that they belong to the shipborne MiG-29K version, where the increased thrust achieved by the installation of a new fan with increased air consumption supports ramp takeoff from the short deck of aircraft carrier. An integrated digital regulating system for the engine is envisaged that also devises control commands for the flaps of the air intake.

The MiG-29M, as opposed to its predecessor (intended by and large for the destruction of airborne targets), is a true multirole tactical fighter with a rich arsenal of air-to-surface guided weapons. The war in the Persian Gulf visibly demonstrated the decisive significance of so-called "smart" weapons. R. Belyakov relates that many potential export customers have appealed to the OKB to expand the capabilities of the MiG-29 in operations against ground targets.

The weapons control system (SUV) on the MiG-29M is a new one. Its foundation is the multifunctional pulse-Doppler radar developed by the Fazotron NPO [Scientific-Production Association], operating with high, medium and low pulse repetition rates. The antenna is a planar slit array. Even though the range of airborne target detection has effectively not increased, the variety of operating modes and the "intelligence" of the set, including jamming protection, has become substantially more extensive.

The air-to-air modes include tracking of up to ten targets in fire-and-forget mode, and the simultaneous firing on two to four of them in open space or against the ground. The automatic lock-on of targets from vertical-scan mode is provided in close-range air-to-air combat.

The set of air-to-ground modes is very broad—mapping with a active beam and synthesized aperture, enlargement of the scale of depiction of a selected plot on a map ("electronic loop") and "freezing" of an image, measurement of the intrinsic speed of the aircraft to correct the navigational system and to compensate for the wind when delivering non-guided weapons, measurement of the coordinates of selected land or sea targets and support of low-altitude flight with automatic obstacle avoidance.

The electro-optic portion of the SUV has also been substantially refined. The optical-locating set (OLS) is equipped with a new and sensitive infrared receiver with deep cooling, which has increased many times over the range of target detection from thermal emissions. The power of the laser channel has also been boosted, and the boundaries of the range determination of both air and land targets have been expanded accordingly. The new OLS moreover supports the detection of a laser spot on a ground target illuminated by an external target designation source, as well as the delivery of semi-active air-to-surface missiles with laser homing (Kh-25ML and Kh-29L). Up to four such missiles may be accommodated on the internal stores racks under the wings.

The OLS also has another television channel, which provides for the identification of air and ground targets at greater than visual ranges. There is a mode for the televised correlation tracking of a ground target. Kh-29T guided missiles and adjustable KAB-500KR aerial bombs with television homing heads may be delivered either singly or in salvos. The helmet-mounted target-designation system has also been modified, by and large with the aim of reducing the weight of the gear.

The aircraft cockpit has two multifunctional electronic indicators and a new head-up display (ILS) indicator. The concept of command and control of all SUV modes without removing the hand from the aircraft control stick or the engine control levers has been realized on the MiG-29M. The ILS has become the principal piloting instrument, and the small piloting instruments with round dials in the center of the instrument panel are only back-ups in the event of the failure of the electronic indicators. The "ahead and down" field of view has been improved (to -15°) through the raised position of the pilot in the cockpit.

The MiG-29M has the same 30mm GSh-30 cannon, but its ammunition load has been reduced from 150 to 100 rounds. The general designer explained that "the cannon is principally employed against aerial targets. The MiG-29M is provided with high aiming precision, and just five to seven shells are required to shoot down a target."

The number of wing stores racks has been increased from six to eight, while the central one under the fuselage has been preserved. This provides for a maximum bomb load of 4.5 tonnes (nine 500-kilogram bombs).

The capabilities to counter the opposition of PVO [air defenses] have been raised substantially. An active jamming set and gear to warn of illumination (SPO) have been installed on the MiG-29M, and the store of jamming rounds has been increased from 60 to 120.

The SPO can not only warn the pilot, but also control the passive antiradar heads of the Kh-25MP and Kh-31P missiles, of which the MiG-29M can carry up to four. The Kh-25MP missile has a mass of about 320 kg and a maximum launch range of up to 40 km, and is intended principally to defeat the Hawk SAM radar. The Kh-31P high-speed antiradar missile, with a ramjet engine developed by the Zvezda NPO, can defeat all existing homing and fire-control radars of contemporary SAM systems, including the Patriot, as well as the detection and warning radars of air-defense systems. Its launch range is up to 100 km, with a mass of about 600 kg.

The air-to-air weapons include the latest development of the Vympel MKB [Design Bureau]—the RVV-AE missile with an active homing head. This is the domestic analogue to the American AMRAAM missile. The RVV-AE has inertial guidance with radio correction and active radar homing on the final leg of its trajectory, making it possible to fire on several targets simultaneously. The MiG-29M is armed with eight such missiles, which gives it a very impressive appearance. The missile can defeat targets maneuvering at up to 12 Gs. The maximum launch range on closing headings and at high altitudes and speeds reaches 100 km, but a value of about 40 km can be considered typical for the conditions encountered most often.

The number of R-27 semi-active missiles accommodated has been increased to four, two of which can be R-27RE with a launch range increased to 130 km. Even though the full maximum launch range of this missile is not realized on the MiG-29M owing to their limited lock-on range, their use could nonetheless prove to be decisive in a closing missile battle at medium ranges. A missile with increased power has a higher average flight speed, and the gain of a few seconds in hitting the enemy deprives his semi-active missile the opportunity to continue guided flight.

The Mikoyan OKB has always assigned great significance to reliability and maintainability in its aircraft. No less attention is devoted to those aspects today than to the tactical flight characteristics or the features of the SUV. General Design R. Belyakov reported that the average run time between failures for a MiG-29M will be no less than eight hours, and the combat readiness of the fighter fleet will be at the 90-percent level. The average duration of the pre-flight preparations for a solitary aircraft is 30 minutes, and the time to prepare for a repeat sortie is 15—25 minutes, depending on the choice of weaponry. The total unit labor-intensiveness of maintenance is 11.5 man-hours per hour of flying time. The average time to restore an operable state should not exceed 1.2 hours, with a frequency of routine maintenance operations of 200 hours. The time necessary to replace an engine is 2.2 hours, including breaking it out, greasing it and testing, with a labor-intensiveness of 5.3 man-hours.

The MiG-29M should be a long-lived aircraft, with its life cycle extending well into the next century.

The fate of the new fighter could shape up in different ways, owing to the sharp cutbacks in defense spending. First Deputy General Designer A. Belosvet describes the situation thus: "A fundamentally new financial program has been lined up and signed for this aircraft. It should go to the Air Forces, which will evaluate it and perform field testing. The Air Forces are essentially running the program."

World practices really do not know any examples of the sale of a combat aircraft abroad that is not in service with the manufacturing country. Several years ago the American firm of Northrop tried the creation of a special export fighter, the F-20, but even the Third World countries refused to acquire it, preferring to pay more to obtain the U.S. Air Force tested F-16 from General Dynamics.

R. Belyakov feels that the opportunities for the export of the MiG-29M are very good: "This multirole aircraft, with the highest effectiveness in the performance of both air-to-air and air-to-ground tasks, is a twin-engine aircraft, which is very important for operational safety in peacetime. It has small reflecting surfaces compared with its competitors, and a small signature. We feel that it will find application."

The OKB imeni A.I. Mikoyan is also offering collaboration to European countries in the creation of a new European fighter based on the MiG-29M and further developments of it. The new Eurofighter that is now under development, in the prestigious opinion of the general designer, is in no way superior to the MiG-29M. This proposal is being discussed with interest in aviation circles and in the pages of the foreign press, but "the reaction so far is guarded."

More evidence in favor of the MiG-29M is the fact that relatively larger and more expensive aircraft such as the McDonnell-Douglas F-15 can be acquired only by Israel, Japan and Saudi Arabia. The Grumman F-14 was procured by Iran alone during the rule of the shah, and Russia has supplied the Su-27 only to China. The number of countries supplied with the F-16, a close analogue to the MiG, is approaching twenty.

The reason for that is simple—the cost of the aircraft is connected directly with its takeoff mass, and that is not only the production price but also the cost of servicing and operation, which comprise the greater portion of overall spending over the life cycle. An aircraft with a takeoff mass of 15 tonnes understandably requires half the kerosene for a flight of one hour in duration or a ferry of 600 kilometers than a craft weighing 25 tonnes. Today, when our country is also coming out at world market prices, this factor obviously can no longer be disregarded.

Beginnings of Kazakh Air Forces Considered Promising

93UM0679F Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 2, Feb 93 (signed to press 9 Feb 92) pp 32-33

[Article by Lieutenant-Colonel M. Syrtlanov under the rubric "Military Reform: In the Air Forces of Commonwealth Countries": "The Virgin Skies of Kazakhstan"]

[Text] Judging by the constructive solutions to economic and social issues, the Republic of Kazakhstan intends to make intelligent use of its skies as well. The first steps in the emergence of the national army already testify convincingly to the steadfast attention that is being devoted in the republic to the formation of their own air forces. This process is being conducted on the basis of the realities of the current day and experience that has been obtained—both their own and that of the leading aviation powers of "near" and "distant" foreign lands—and is, most importantly, figured for the long term.

"We have to solve difficult problems in the course of military reform. But knowing my people, I am convinced that we can manage it," was the opinion of the first commander-in-chief of the Air Forces in the history of the resurrected nation, Deputy Minister of Defense of the Republic of Kazakhstan for Aviation Major-General of Aviation A. Volkov. At the beginning, you will agree, faith in oneself and one's subordinates is a factor of no small importance in achieving success. Recall what is happiness for a commander—when you rise up to attack and don't have to look around.

There is another circumstance deserving of respect that cannot fail to be mentioned when analyzing the process of military reform in the republic as a whole. Having gained the genuine right to sovereignty, Kazakhstan has not rushed to affirm itself at a forced pace with the break-up of old structures or the complete rejection of the gains of the past. Everything that is valuable and useful has been taken up here with the zealousness of the far-sighted master. Taking into account the fact that they had to begin the creation of their own armed forces in parallel with defining the "outlines" of the future military doctrine and the conceptual framework for military organizational development, this stance appears to correspond the most to common sense.

The Air Forces of the republic will include units and subunits of bomber, fighter/bomber, fighter, reconnaissance, transport and army aviation from the composition of the Air Forces of the former USSR. The Ministry of Defense of the Republic of Kazakhstan, in accordance with that decision, has already worked out the principles for the creation of the services dealing with pay, food and clothing, and has thought out ways of upgrading the aircraft inventory in the future. On the agenda are making the structure of the Air Forces more efficient, concluding agreements for the delivery of combat hardware and its repair, and interaction with other nations of the CIS that have signed the "Collective Security" Treaty. Then it will obviously be possible to discuss the training of national cadres for the Air Forces.

It would be incorrect, by the way, to assert that the difficulties of an economic nature that have come up in all the republics of the former USSR have bypassed Kazakhstan. But here they have been able to overcome the evil costs of the stagnant order despite everything.

Life sometimes dictates its own terms when determining the expediency of this or that solution. When it was necessary to replace engines that had used up their service lives on some combat aircraft, they had to make barter deals with the Air Forces of a neighboring republic that at the time had an acute need for airfield servicing and support vehicles. One need not be an authority on marketing to define something like that, I would say, as vulgar entrepreneurship in the sphere of military organizational development. But where do you go if there is no other way out, and one is not seen in the foreseeable future?

The problems being discussed are far from simple ones. Deliveries of assemblies and spare parts, as well as fuel, have been cut back as a result of the disruption of production and other ties. While they are getting out of the situation somehow with parts, the lack of fuels sometimes forces them to plan flight shifts only in amounts that barely support the maintenance of the proper level of training proficiency of the crews.

The question of manning many aviation units and subunits with personnel remains unresolved. The chief of staff of the Air Forces of the republic, Major-General Yu. Shanin, who has served 15 years in Kazakhstan, elaborated that certain military collectives have a shortfall of officers of roughly 10 percent, and of warrant officers of up to 30 percent. Add to that about seven hundred in line to obtain housing, and it becomes clear how important it is to maintain those people with a good word, to demonstrate concern for them. We can thus understand the commander of the Air Forces of the Republic of Kazakhstan, Major-General of Aviation A. Volkov, who has been looking after the social protections of the servicemen and inveighing for an expansion of housing construction at the aviation compounds since the first day he took up his position.

Even in Moscow before my departure on the trip, I read in a newspaper about the supposedly oppressed situation of the Russian-speaking population living in the republics of Central Asia. I do not know about elsewhere, but Kazakhstan does not deserve such a frankly provocative reproach. Dispassionate statistics confirm, on the contrary, that the republic must provide for an influx of specialists of the indigenous nationality into the army even today. It is one thing that the local youths used to enter the military schools or warrant-officer schools unwillingly. It is another thing—and this must finally be frankly acknowledged—that even those who linked their fate with military service rarely received the right to serve in their own land, and even more rarely had the opportunity to make a military career. Even though the zealous attitude of Kazakhs to the fulfillment of their service obligations is well known to all, some had to share with them the burden of military service.

I want to be understood correctly. The attraction of Kazakh youth to take part in the defense of their homeland is not an end in itself. The presence of national cadres not only in the Air Forces, but first and foremost in them, will sooner or later ensure the stability of the military policy of Kazakhstan and eliminate the negative consequences of migration processes, which have already started whether we like it or not. Whence the tasks of military-patriotic indoctrination of the youth and propagation of the combat traditions of their countrymen that are being advanced to the command of the units and subunits by Minister of Defense of the Republic of Kazakhstan Colonel-General N. Nurmagambetov. The leadership of DOSAAF, which is continuing to devote the most steadfast attention to the development of air clubs, also sees a role for itself in this important cause.

Yes, when gathering the first harvest, one must already be thinking about tomorrow—so as to cultivate worthy successors to the aviation glory of the republic, successors to front-line soldier and two-time Hero of the Soviet Union Talgat Begeldinov and other aces of military times.

The considered approach of the leadership of the republic to the realization of the program of military reform confirms that the upturned virgin lands of the Kazakh skies, protected by mighty wings, will provide good shoots without fail.

GEO-IK Satellite System for Research and Geodesic Support

93UM0679G Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 2, Feb 93 (signed to press 9 Feb 92) pp 38-39

[Article by Colonel Yu. Rusakov and Colonel V. Gorev under the rubric "Space Science—For the National Economy": "The Space Geodesist"]

[Text] Geodesy is the science of the Earth, studying its shape, structure and evolution, and one part of it—space geodesy—performs those same tasks with the aid of spacecraft.

A state geodesic network—an aggregate of geodesic points located in a certain order on the country's territory—has been created and is being developed for practical utilization, and is subdivided into classes depending on the distance between the points and the precision of their determination. The use of spacecraft makes it possible to clarify the coordinates of points on the state geodesic network of the first class and develop it in inaccessible regions, as well as to perform geometric and dynamic tasks of geodesy.

The geometric tasks are reduced to determining the position of points on the Earth's surface and establishing the geodesic ties between continents and islands to adjust them to the uniform global system of coordinates, reference individual points and objects to triangulation networks and provide support for cartography. The shape and dimensions of the Earth are clarified, and potential gravitational anomalies of the field and the laws of changes in them are determined.

This is accomplished via precise measurements and strict mathematical calculations, the processing and analysis of which make it possible to determine the nature of the movements of individual portions of the Earth's crust, help to ascertain typical indications of the precursors to earthquakes and, in the future, to predict them.

All are familiar with the scope of the misfortune that natural disasters, and earthquakes in particular, bring to mankind. There are an average of 20 powerful tremors around the globe every year, one of them catastrophic. There are more than 100,000 a year in all. They lead to significant and rapid changes in the Earth's crust. The shifts in height ranged from 1.71 to 3.47 meters in Japan in an earthquake in 1923, while in India there were shifts on the order of 1.4 meters in 1934.

The slow movement of the Earth's crust also brings many unpleasantries. The inhabitants of coastal regions of Holland have been battling the encroaching seas for centuries now, building and augmenting dikes in their path. Some harbors and straits in Scandinavia, on the other hand, have become so shallow that they can no longer receive oceangoing vessels as a result of the uplifting of the land. The capital of Mexico, Mexico City, dropped an average of 5.6 meters from 1880 to 1956, and Tokyo 3.5 meters in this century alone, with a tenth of that city ending up in the Pacific Ocean. The same fate threatens Venice. The settlement of the soil in cities occurs from the vibration of thousands of machine tools, urban transport engines and engineering explosions. It has been established that the buildings are settling two or three times faster on major streets in Moscow than on side streets. The settlement is still measured just in millimeters over several decades, but it must be taken

into account in the same way as the movements of the Earth's crust in the areas of oil and gas pipelines, mineral fields and reservoirs.

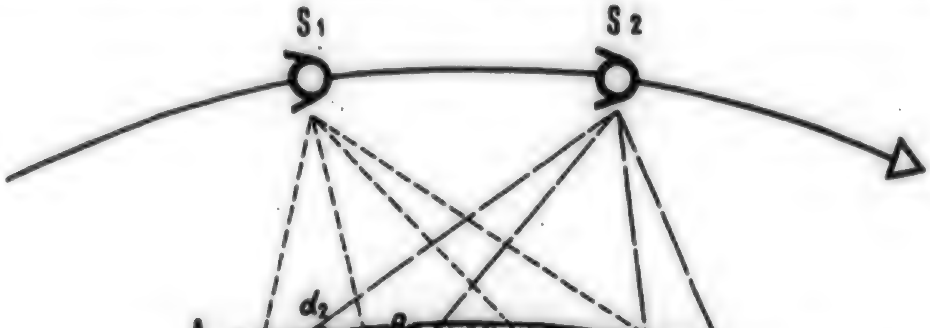
Anomalies in the force of gravity that arise as a consequence of the uneven distribution of the Earth's density reflect its internal structure, especially of the Earth's crust. Space geodesy is thus widely used when researching the structure of the Earth, prospecting for minerals and studying seasonal changes in meteorological factors such as the yearly and daily fluctuations in atmospheric pressure, the level of ground water, soil moisture content etc. The gravitational field affects the trajectory of the flight of shells, missiles and satellites; that is why the role of gravimetric determinations is exceptionally important.

The methods of space geodesy are founded on observations from Earth satellites, used as mobile aperture sights with coordinates that are known at the moment of observation (flares or missiles dropped by parachute from a high-flying aircraft or balloon were used in the 1920s). The essence of one of the methods (synchronized) is as follows. We have two initial points A and B and two points to be determined C and D (see figure). In order to calculate the coordinates of the latter, it is sufficient to measure simultaneously, and in a uniform system, the coordinates of the vertical and horizontal angles to the satellite at no fewer than two positions. The solid angles α_1, α_2, β_1, β_2, γ_1, γ_2, δ_1 and δ_2 are computed according to them. The points S_1 and S_2 are then obtained by solving the triangles ABS_1 and ABS_2, and the coordinates of the unknown points C and D from the shape S_1 S_2 CD. It is necessary to have a minimum of three initial points and two observations of the target position from above for a more reliable determination of the coordinates of an aperture sight. The data are processed using the least-squares method.

Optical (angular and rangefinder) as well as radio (rangefinder, Doppler) systems measuring the position of the craft in relation to ground points are used to reference points relative to which the spacecraft is located in the field of view over a certain period of time (or simultaneously). The high precision of the measurements is ensured by fixing the time of measurement as set by the on-board standard.

Work on the creation of a uniform system of coordinates for the whole Earth's surface and the establishment of geodesic links between continents and islands was begun in our country in 1973 using Kosmos series spacecraft. The GEO-IK geodesic system is currently in operation, and makes it possible to perform the basic and applied tasks of creating a basic astronomical-geodesic network and regional geodesic networks for Antarctica, Europe and Asia, including the geodesic referencing of islands, supporting operations on the Pacific shelf, determining the characteristics of the Earth's gravitational field and the maritime geoid and the parameters of the rotation and shape of the Earth, as well as the foundations for topographic pictures of major objects under construction.

The system includes a space segment, including one or two satellites, a ground command-and-control system for the craft and a land-based geodesic system with a center



for the processing of special information and an observation point (up to 80 points on the entire Earth's surface).

The spacecraft are placed in circular orbits 1,500 kilometers high, with an inclination of 74° or 83°, by a Tsiklon launch vehicle from the Plesetsk cosmodrome. The distance between the reference points is up to 6,000 km. The support zone is the entire surface of the Earth, including the polar regions. The craft is equipped with a gravitational orientation and stabilization system, a system for light signaling, angular reflectors with an effective area of 0.024 m^2 and a radio system, including a radio altimeter (accuracy of measurement of altitude to sea level of 3—5 meters), a Doppler system and a transmitter for the rangefinder polling system.

The ground stations include radio Doppler gear supporting measurement of the radial component of the spacecraft velocity in non-polling mode relative to the ground observation point (mean square error of 1—3 cm/sec), an astronomical installation to determine the direction to the spacecraft (mean square error of 1.5"), radio rangefinding polling gear for measuring the distance from the ground observation point to the craft (mean square error of 3—5 meters) and a laser rangefinder for these same purposes (mean square error of 1.5 meters).

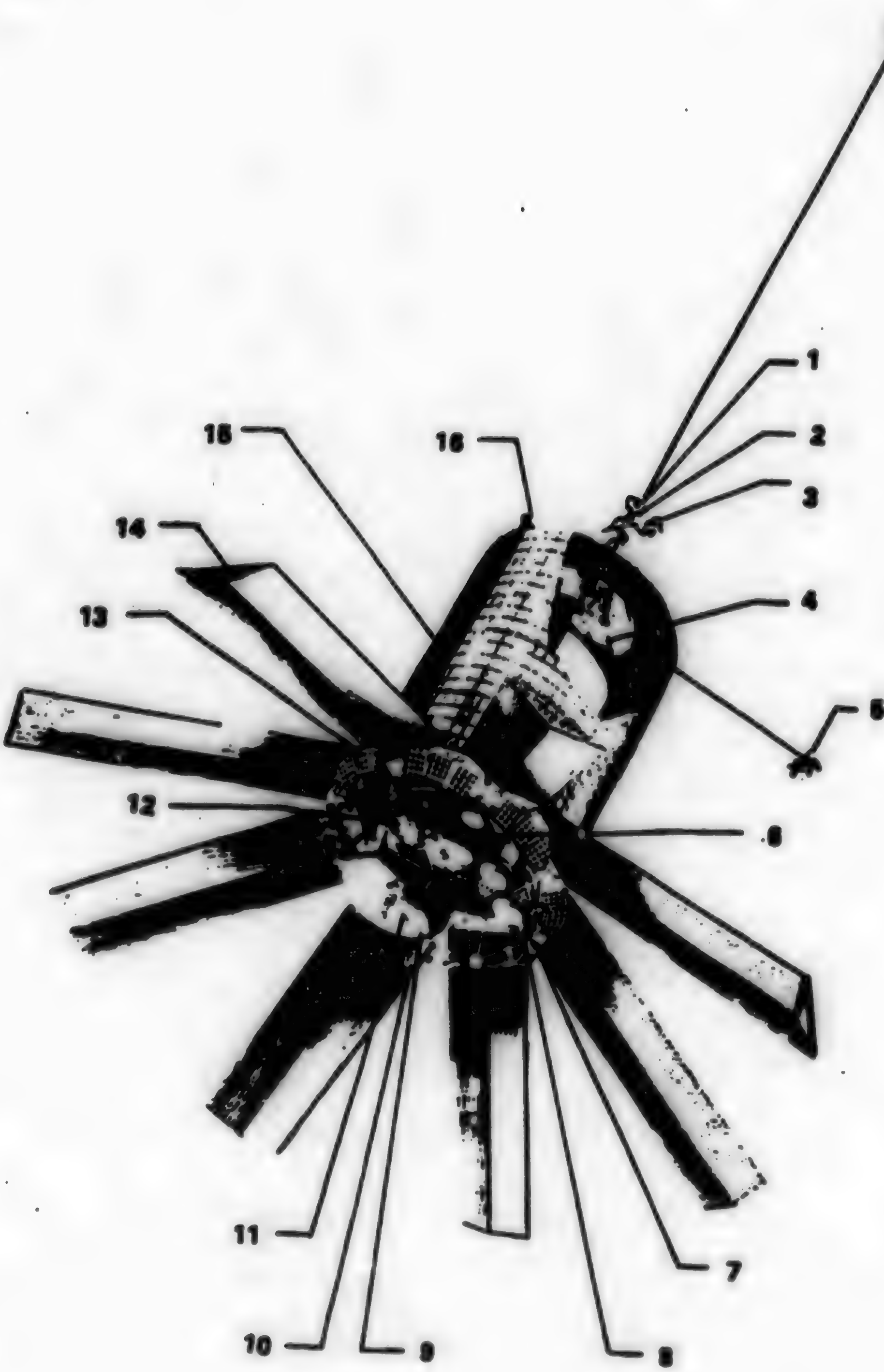
The information received from the ground observation stations on the communications channels comes to the center for processing special information, where a database is created from which all of the information is issued by the computer upon customer request. The number of users is unlimited. This information, along with traditional means, makes it possible to perform the tasks of geodesy. The space geodesic systems support the creation of regional geodesic networks, the foundations for mapping, the fulfillment of requests for coordinate references of points in a required system of coordinates etc. with higher quality, and some tasks only it can perform (supporting operations on the Pacific shelf, studying its topography, geodesic referencing of islands). Gravimetric surveying using spacecraft considerably accelerates the study of the Earth's gravitational field.

Analogous work on the creation of a state geodesic network is underway in the United States, where the WGS-84 system of geodesic parameters, allowing support for a precision of the determination of geodesic points of 1—2 meters, is the foundation. The Geos-3 and Geosat spacecraft, among others, have been used for these purposes. The coordinates of ground points and the relief of the ocean surfaces have been determined, the shape of the geoid has been clarified and a gravitational model of the Earth has been created using them. The Lageos-2 craft is currently in orbit The launch of the Gravsat-A and Gravsat-B, which should provide for the measurement of parameters of the field with a precision of 0.1 meters for the height of the geoid and the determination of the acceleration of the field of gravity with a precision of 1 mgal (0.001 cm/sec^2), is planned to study the fine structure of the Earth's gravitational field.

Navigational spacecraft are also used to develop the geodesic network and perform individual geodesic tasks.

The GEO-IK spacecraft system

Key:
1. sun position sensor
2. gravitational device
3. receiving antenna for the command-program apparatus (transmission at 1,200 MHz, reception at 1,000 MHz)
4. sealed instrument container
5. magnetometer
6. transmitting and receiving antenna for the command-program apparatus (transmission at 1,200 MHz, reception at 1,000 MHz)
7. light instruments
8. transmitting and receiving antenna for the rangefinding apparatus (transmission at 3,400 MHz, reception at 5,700 MHz)
9. combined antenna for the Doppler system (150 and 400 MHz)
10. infrared local reference vertical plotter
11. orientation antenna for radio altimeter (9,500 MHz, directional pattern width 2°
12. two-stage dual gimbals
13. laser-emissions reflectors
14. solar-array panels
15. thermostatic solar array
16. Earth sensor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History of Soviet Lunar Program After N1-L3

93UM0679H Moscow AVIATSIYA I KOSMONAVTIKA in Russian No 2, Feb 93 (signed to press 9 Feb 92) pp 42-44

[Article by I. Afanasyev under the rubric "By Reader Request": "The 'Lunar Theme' After N1-L3"]

[Text] *Readers of our journal who have become familiar with the N1-L3 project (AVIATSIYA I KOSMONAVTIKA No. 12 of 1991 and Nos. 1, 2 and 9 of 1992) have noted that the story of the Soviet lunar program was seemingly broken off in midsentence. Taking into account the wishes of I. Konyukhov from Leningrad Oblast and R. Gnatyuk from Ukraine, among others, we are continuing to cover the work on lunar topics that was conducted in the USSR after the events described earlier.*

V. Mishin, who headed the Central Design Bureau for Experimental Machine Building [TsKBEM] after the death of S. Korolev, facilitated the pursuit of the lunar program with all of his strength. But the leadership of the sector and the country, under the impact of the successful landing on the moon by the American astronauts, felt the accomplishment of the N1-L3 project in its initial version to be without prospects. The rapid shutdown of the program did not follow, however, owing to the enormous amount of work that had already been done, even though the financing and pace were reduced sharply. They were evidently still nursing the hope "on high" that something would throw off the Americans, and then it would be possible to make up what had been omitted and "jump ahead" with a vigorous push.

The aimlessness and ambiguity of this position were obvious. In order not to lose accumulated experience and simultaneously to reach the assigned goal—to land on the moon—the TsKBEM developed, at the suggestion of V. Mishin, a variation of a lunar space-rocket system—the N1-L3M. It was broadly proposed to speed up the N-1 launch vehicle and create a new ship for the flight according to an original, dual-launch system. The preparation of the necessary infrastructure for the emplacement of a lunar base in the not-too-distant future and the performance of expeditions of moderate duration (up to three months) was planned, instead of short-term visits to the surface of the "night luminary." It turned out that a real possibility of the fulfillment of the new program could appear as early as 1978-80, and under financing that did not go beyond the bounds of the budgetary appropriations for the N1-L3.

The insufficient reliability of the docking of the lunar orbital craft (LOK) with the lunar craft (LK) launched from the surface of the moon was deemed to be one of the weakest areas of the N1-L3 project. The fault for that was the poor capabilities of the electronic systems of the craft, the insufficient extent of the study of the conditions of navigation close to the moon and the impossibility of giving the cosmonauts comprehensive and prompt support from Earth, as was done in the docking of craft in near-Earth orbit. New approaches were required.

A flight according to the "direct configuration" without dockings in orbit would have been simple, but not economical. The whole ship makes the landing on the moon in that case. After the fulfillment of the research program, the returnable portion of the craft launches from the moon, while the re-entry craft (SA) separates from it as it approaches the Earth and enters the atmosphere with second escape velocity, with a controlled descent and parachute landing. A launch vehicle (RN), however, had to be created for such a flight, using even the simplest and lightest craft, that would have had approximately one and a half times the lift capacity of the N-1.

The possibilities for the gradual augmentation of the mass of the payload had been made inherent in the N-1 project from the very beginning, but only the acceleration of the first stage of the N-1—which would add only about 10—11 percent to the payload mass—was realistic in the near future.

It was thus decided to stick with a modified version of the "direct configuration," in which the lunar craft and the braking rocket unit would be launched into near-Earth orbit separately with their own N-1. Each would then first reach flight trajectory to the moon with the aid of its own starting and braking engines (RTB), and then selenocentric orbit where the docking would occur. If the docking were to fall through, the cosmonauts would return to Earth. The braking unit would be used for the descent of the LK from lunar orbit and to shed speed, and it would then separate at a certain height above the moon's surface. A soft landing took place with the aid of the engine installation (DU) and the landing struts of the LK. The separation of the landing adapter and liftoff with the engine of the LK operating at full thrust were necessary for return. The ship was to enter a selenocentric orbit after launch from the moon, from which it would take a heading toward Earth or shift at once onto a return trajectory.

The use of the "direct configuration" made it possible to equip the craft with a complicated system of more advanced radio gear for the precise and reliable performance of maneuvers connected with searching, meeting and docking in lunar orbit. Such a larger LK would moreover have had greater freedom of maneuver close to the surface to select a landing site.

The creation of some new elements of the system was envisaged in this project, along with the widespread utilization of the work that had been developed under the N1-L3 program. While a somewhat modified D unit from the L-3 could have been used as the braking unit, the craft itself and the RTB had to be created virtually anew.

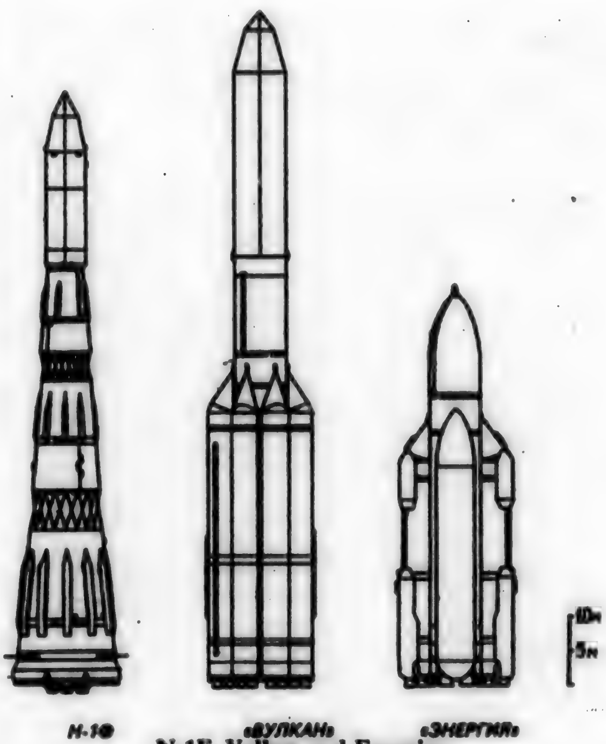
The RTB, replacing the G unit and partially the D unit of the L-3 system in the N1-L3M project, was to become

the first Soviet high-energy stage. The installation of four oxygen-hydrogen ZhRDs [liquid rocket engines] was proposed, and their development entrusted to the OKB [Experimental Design Bureau] of A. Isayev in the second half of the 1960s. And while only drawings had come out for the RTB, the ZhRDs were brought to the stage of live ground tests. The first Soviet cryogenic engine, built according to an improved, self-contained configuration, proved to be very economical and reliable. It surpassed the analogous American ZhRD, developed by the firm of Pratt and Whitney for the upper stage of the Atlas-Centaur launch vehicle. The design bureau continued to improve the engine despite the shutdown of the lunar program, making it competitive in the world markets. Several of the first flight models of this ZhRD and the technical documentation for its manufacture under license will thus be sent under contract to the India Space Agency.

The craft itself for the N1-L3M project was outwardly somewhat reminiscent of the L-3 LK system. It consisted of a DU that was, as a whole, analogous to the Ye unit of the LK of the L-3 project, with the lunar landing installation attached underneath and the cocoon-shaped habitation module (OB) above. The engines of the DU were backed up, operated on long-term storable, self-igniting fuel and had the capability of thrust regulation across a broad spectrum. The OB had the re-entry craft, with an airtight instrument compartment in the lower portion. The cosmonauts were to leave the SA and operate within the internal spaces of the OB during various operations in flight and on the lunar surface, providing not only freedom of access to the control instruments but also a good view, easing the choice of landing site. The separation of the OB and the departure of the SA from it occurred when approaching the Earth.

After the successful completion of th Apollo program, the Soviet lunar project lost its prestige in whatever form it was. Money for the N1-L3M variation was not allocated. The program to assimilate the moon was moreover re-oriented toward unmanned flights, with a gradual reduction in the number of launches of automatic stations and the subsequent curtailment of that program under the slogan "The study of the moon is completely finished," owing to delays in the flight testing of the N-1 rocket.

The work on the N1-L3 had effectively been reduced, under pressure from the Ministry of General Machine Building, to the development of the N1 rocket since the very beginning of the 1970s, so as to at least create a launch vehicle. All four of its launches were unsuccessful, which had a depressing effect on the executors of the program and one of *Schadenfreude* for the opponents of the rocket, of which there were more than enough by that time. The creators of the N1 were being "called onto the carpet" more and more, and they had to prove their correctness each time. The rhythm of the work was disrupted owing to the confusion, and rumors were



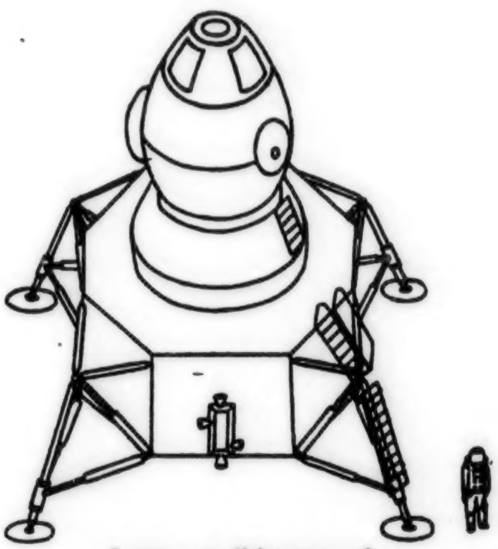
N-1F, Vulkan and Energiya

circulating in the corridors of the "firms" of the supposedly imminent "shutdown" of the N1.

The work on the N1 at the newly formed Energiya NPO [Scientific-Production Association] was curtailed completely a very short time after the removal of V. Mishin from the post of head of the TsKBEM and the designation of V. Glushko for the post in May of 1974.

Academician Glushko proposed the creation of a number of new launch vehicles even before coming to the TsKBEM, formed via the parallel combination of various quantities of standard units. He planned to install a ZhRD with a thrust of more than 1,000 tonnes of force in each of them, in which all of the advanced ideas in the realm of engine building and the great experience of the GDL-OKB that he came from would be employed.

The specialists of the OKB of S. Korolev had criticized that idea as early as the beginning of the 1960s from the standpoint of the non-optimal division into stages, the utilization of toxic components and the lack of conformity to the criterion of cost-effectiveness. The academician, however, skillfully manipulating the terms "reusability" and "universality," convinced the leadership of the country of the necessity of replacing the N1 rocket, which had not proved itself, with a "universal series of reusable launch vehicles," which were to become the foundation of the new conceptual model of the space transport system of the USSR. The staffers of the department developing the N1 spent a whole year after the designation of V. Glushko to the post of head of the



Lunar expeditionary craft

Energiya NPO trying to prove to the new general director the irrationality of creating a new generation of launch vehicles. He was implacable, however, and in October 1974, submitting a comprehensive plan for the association for the next few years, he gave it to be clearly understood that there was no place in it for the N1. But the developers did not get started on the design engineering of such a system, reminiscent of the Glushko "series" only in the most general outlines, until 1976.

One could have thought that V. Glushko shut down the lunar program, but that is not so. He "killed" just the launch vehicle. The academician had an entirely different opinion of the lunar program. One of the paragraphs in his 1974 comprehensive plan envisaged the creation of a long-term scientific-research base on the moon. V. Glushko proposed the lunar expeditionary craft (LEK) as the principal means of transport for delivering cosmonauts and payloads. He proposed it instead with the colossal Vulkan launch vehicle. The new rocket, which went beyond the prior notions of Glushko, was clearly inferior to the N1 in aesthetic terms, even though it won out in characteristics. It had a launch mass roughly 60 percent greater than the N1, could insert a payload of 200 tonnes into near-Earth orbit or deliver 54 tonnes to Venus and 52 tonnes to Mars. The delivery of the LEK to a selenocentric orbit was proposed to be accomplished using the Vezuviy cryogenic unit using an oxygen-hydrogen ZhRD with small thrust but high specific impulse.

N-1F, Vulkan and Energiya Launch Vehicles

Characteristics of the launch vehicles	N-1F	Vulkan	Energiya
Launch thrust, tonnes-force	5,070	7,520	3,600
Launch mass, tonnes	3,025	4,700	2,400
Payload mass:			
—in near-Earth orbit, tonnes	105	200	102
—to fly to moon, tonnes	34	65	35
—for lunar orbit, tonnes	22	43	23

The LEK was created to perform an expedition according to a purely "direct configuration," and consisted of three units—landing and liftoff stages and a habitation module. The landing stage, equipped with a powerful main and four steering ZhRDs, was reminiscent in configuration to the eight-sided descent stage of the Apollo lunar module. The OB and the liftoff stage were similar to those units on the N1-L3M.

One version of the expedition would have the crew launched in an SA located inside the habitable unit of the LEK. The launch of the crew to an unmanned LEK, with the subsequent docking of the craft and transfer of the cosmonauts to the OB of the lunar craft, using a Soyuz placed in orbit separately was proposed, however. The flight of the LEK was otherwise standard for the "direct configuration": launch from near-Earth orbit and entry into lunar orbit with the aid of the Vezuviy RTB, then separation of the LEK from the empty unit and descent to the surface with the aid of the engines in the descent stage. Later, after the cosmonauts had concluded their business on the moon, the takeoff stage was to put the OB onto a flight trajectory to Earth using its own engine. The SA would separate from the OB before entry into the atmosphere.

The country's leadership had no enthusiasm whatsoever for the "new" lunar program, and did not rush to allocate funds to implement the plans of V. Glushko. The task of creating a reusable transport craft that faced domestic space science in those same years pushed the projects on lunar topics into the background. Glushko tried to convince the "higher-ups" of the necessity of financing the program to assimilate the moon until the very last days of his life, but he was not able to do so, even though the development of individual portions of the system reached the preliminary design engineering stage.

In answering the question of whether the possibility of manned flights to the moon exists today, one may say that the Energiya space-rocket system, even in its current state, makes it possible to send a craft to the moon that is greater in mass than the L3. Today, however, there are

neither realistic plans for such craft nor the financial underpinnings for such expeditions.

Articles Not Translated

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